



A Hydrologic Ensemble Seasonal Forecast System over the Eastern U.S.

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January 27/28, 2005
NOAA HDL/NCEP

- n Background and relevance of the east-side hydrologic forecast system to NOAA's climate mission.
- n U.S. east-side hydrologic forecast system
 - n Initial strategy, implementation and evaluation
 - n Expansion of the forecast domain
 - n New multi-model approach under development
 - n Issues related to seasonal predictability and forecast skill
- n Summary and proposed expanded collaboration with NOAA



Background to the Eastern U.S. prediction activities

Builds on earlier NOAA-supported projects

- NLDAS: Development of a Hydrologically-Based Land Data Assimilation System for the Continental U.S.
- Land Surface Predictability Studies at GFDL

Current project's main science question

To what extent are seasonal climate predictions sufficiently skillful to improve hydrologic forecasts and water management decisions, and can this be demonstrated over the Eastern United States?



Relationship of the project to NOAA's Climate Program

Predictions and Projections Objectives

(NOAA Climate Program Plan FY 07 - 11: C. Koblinsky)

Develop a predictive understanding of the global climate system on timescales of weeks to decades with quantified uncertainties sufficient for making informed decisions

- Improve intraseasonal and interannual **climate predictions** to enable regional and national managers to better plan for the impacts of climate variability and change
- Provide improved regional, national, and international **climate assessments and projections** to support policy decisions with objective information.

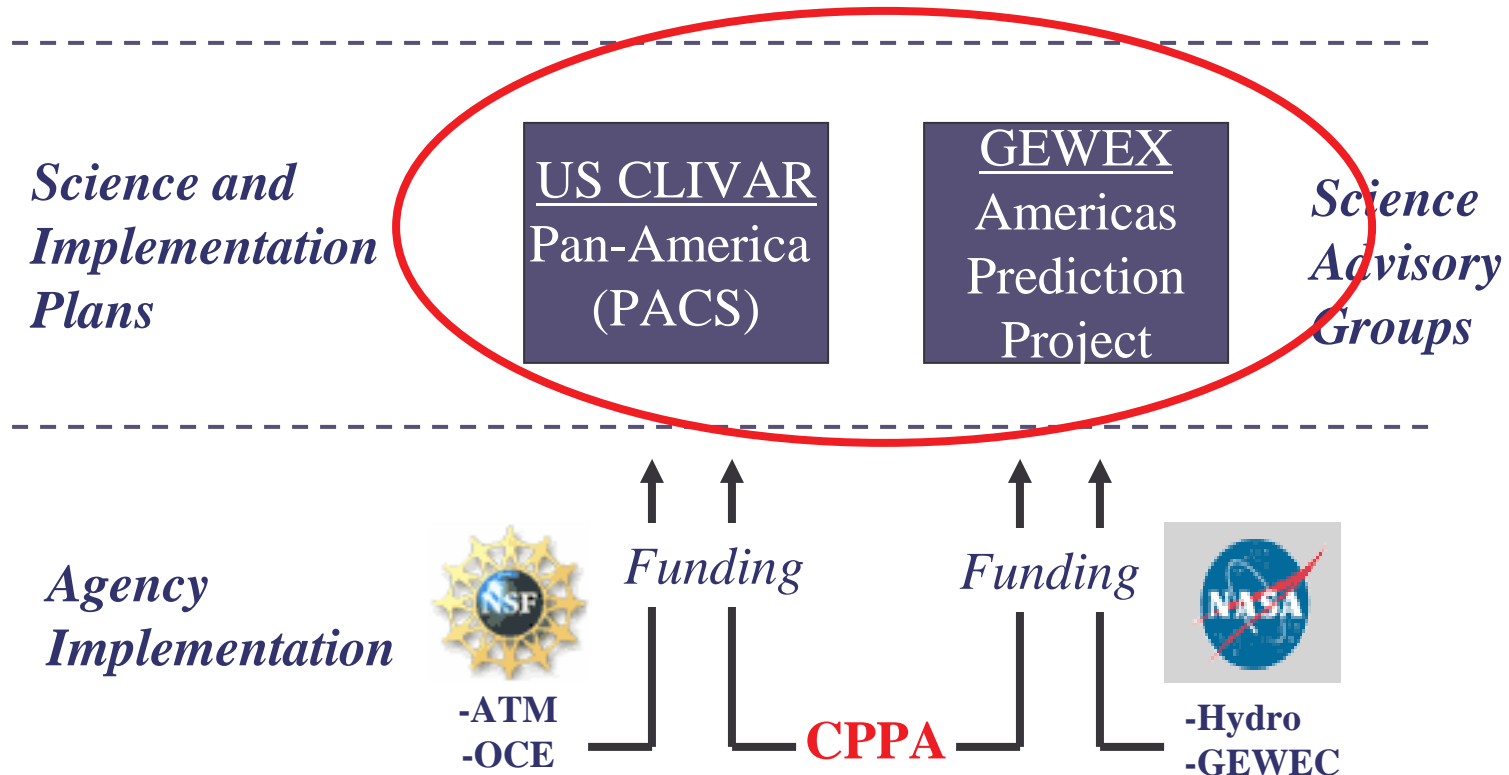
Desired End-State: *A seamless suite of forecasts (e.g. outlooks and projections) on intraseasonal, seasonal, interannual, and multi-decadal timescales and applications using ensembles of multiple climate models in support of the mission outcome “a predictive understanding of the global climate system”:*

FY07: Provide regional resolution forecasts to decision makers through increased computer and model capacity.

FY11: Provide a broader suite of climate forecast products and services through development of Earth System Model.

NOAA OGP/CPPA Programmatic Structure

WCRP COPES (Coordinated Observations and Predictions of the Earth System)



CPPA goal is to improve intraseasonal-interannual climate forecasts and to interpret climate forecasts for better water resource management.

Background to the Eastern U.S. prediction activities

Three detailed scientific issues for the current project.

1. Forecast uncertainty

What are the statistical properties of seasonal climate forecasts, and how does these relate to hydrologic forecast uncertainty?

How does resulting forecasting skill depend on catchment size?

What is the relative role of seasonal climate forecasts versus initial hydrologic conditions as they affect hydrologic forecast skill in the eastern U.S.?

2. Removing seasonal climate model biases

Are there alternative methods to remove seasonal climate model biases in precipitation and temperature?

To what extent can multi-model forecasts lead to lower hydrologic forecast uncertainty?



Background to the Eastern U.S. prediction activities

Three detailed scientific issues for the current project.

3. Generating hydrologic ensemble predictions

How can uncertainties in hydrologic models, model parameters and hydrologic initial conditions be best represented?

How can hydrologic ensemble forecasts be verified, and can the forecasts be used reliably and, if so, over what forecast periods?



US East-side Seasonal Hydrologic Forecast System

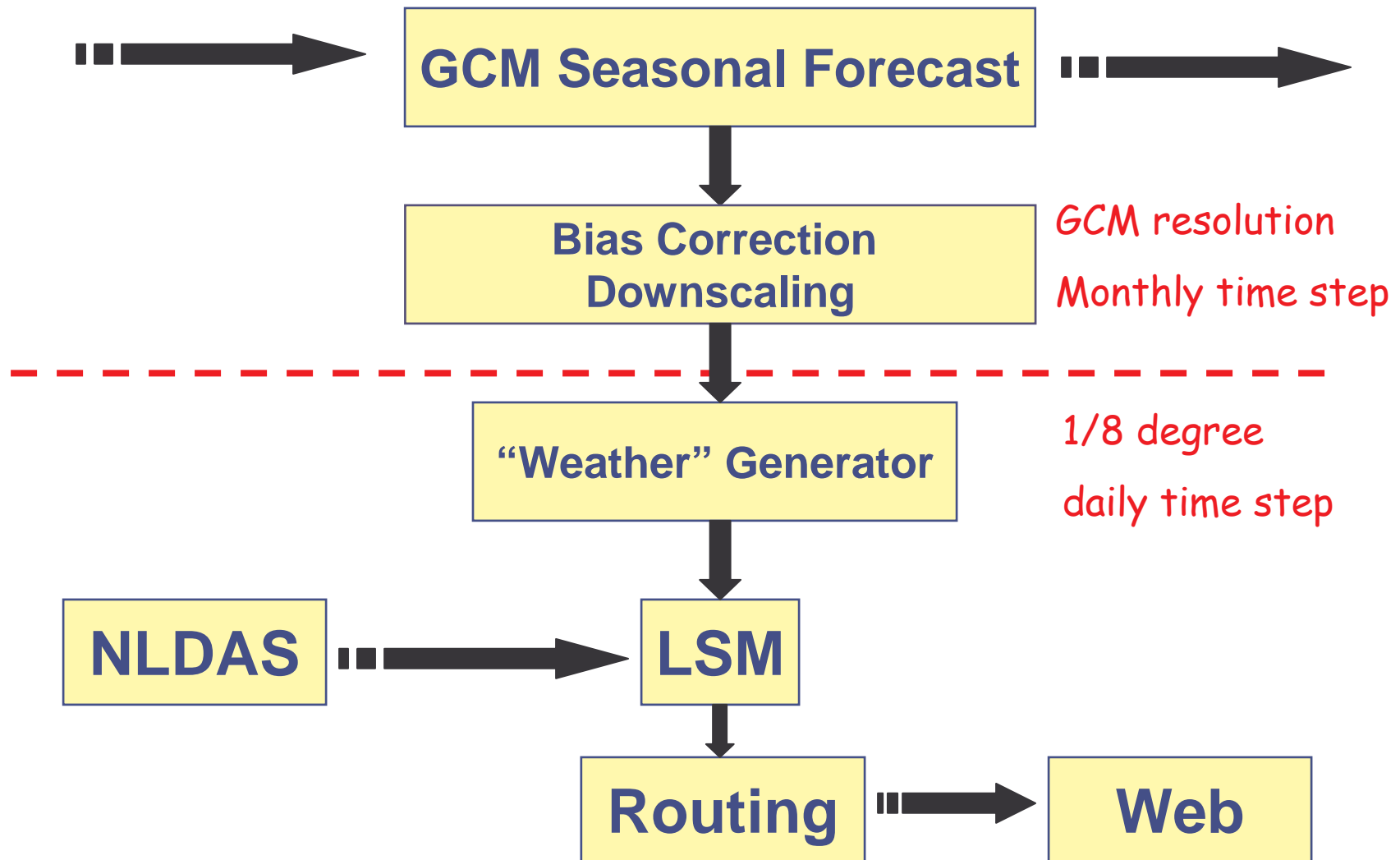
2003: Started development of the Ohio Basin seasonal hydrologic forecast system.

Approach.

1. GSM and NSIPP forecast are used in the seasonal forecast period.
2. Bias correction and downscaling approach same as the Western U.S. system utilizing the UW 50-yr NLDAS retrospective data sets. Corrected at GCM grids and transferred to 1/8th degree.
3. Initial conditions are created using real-time NLDAS forcing running at daily time step (Tmin, Tmax, Precipitation)
4. Day-to-day progression of T and P are taken from historical data, and P scaled to match monthly total precipitation.

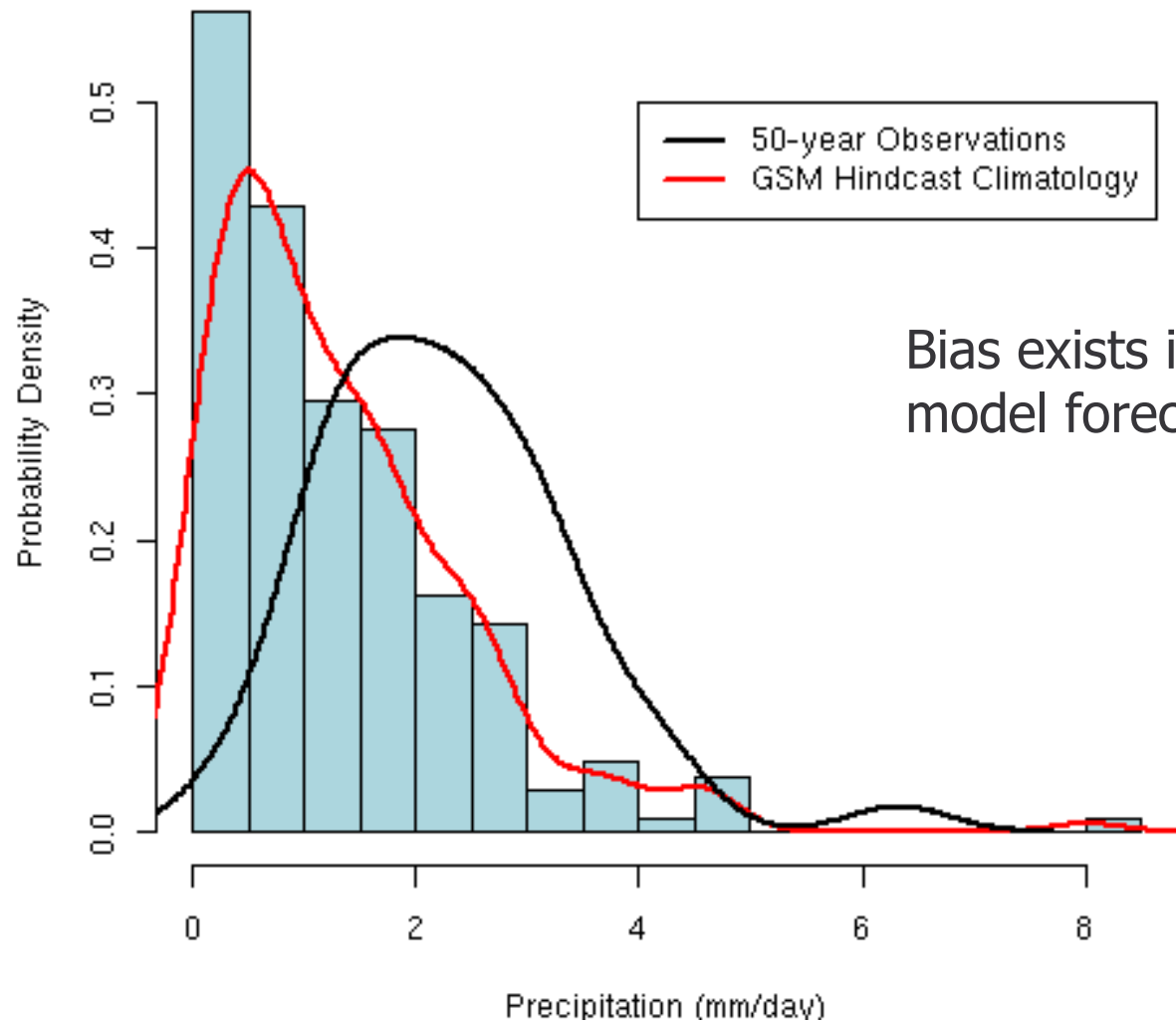


US East-side Seasonal Hydrologic Forecast System



GCM Forcing Bias – Precip.

Monthly Mean Precipitation Distribution

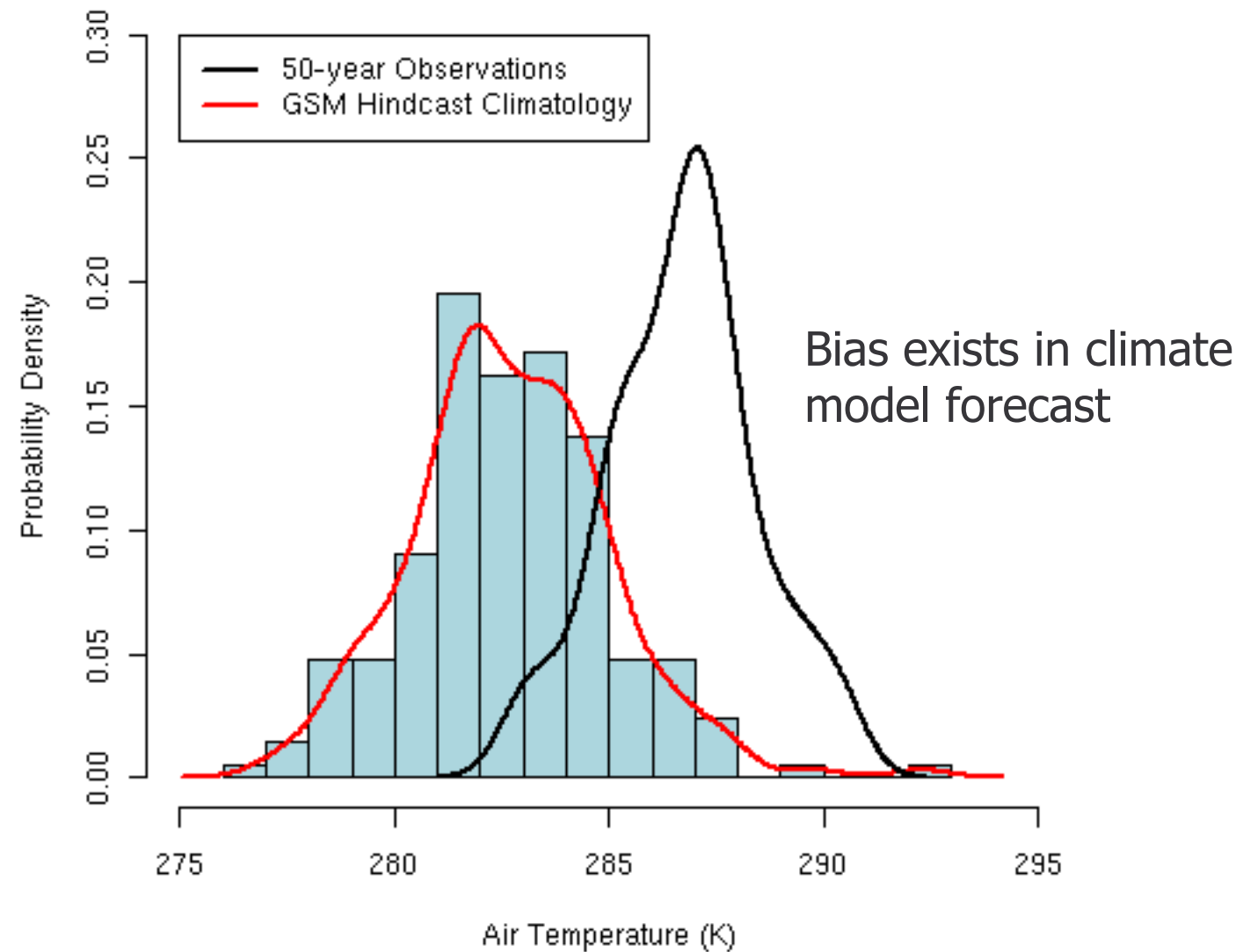


Bias exists in climate model forecast

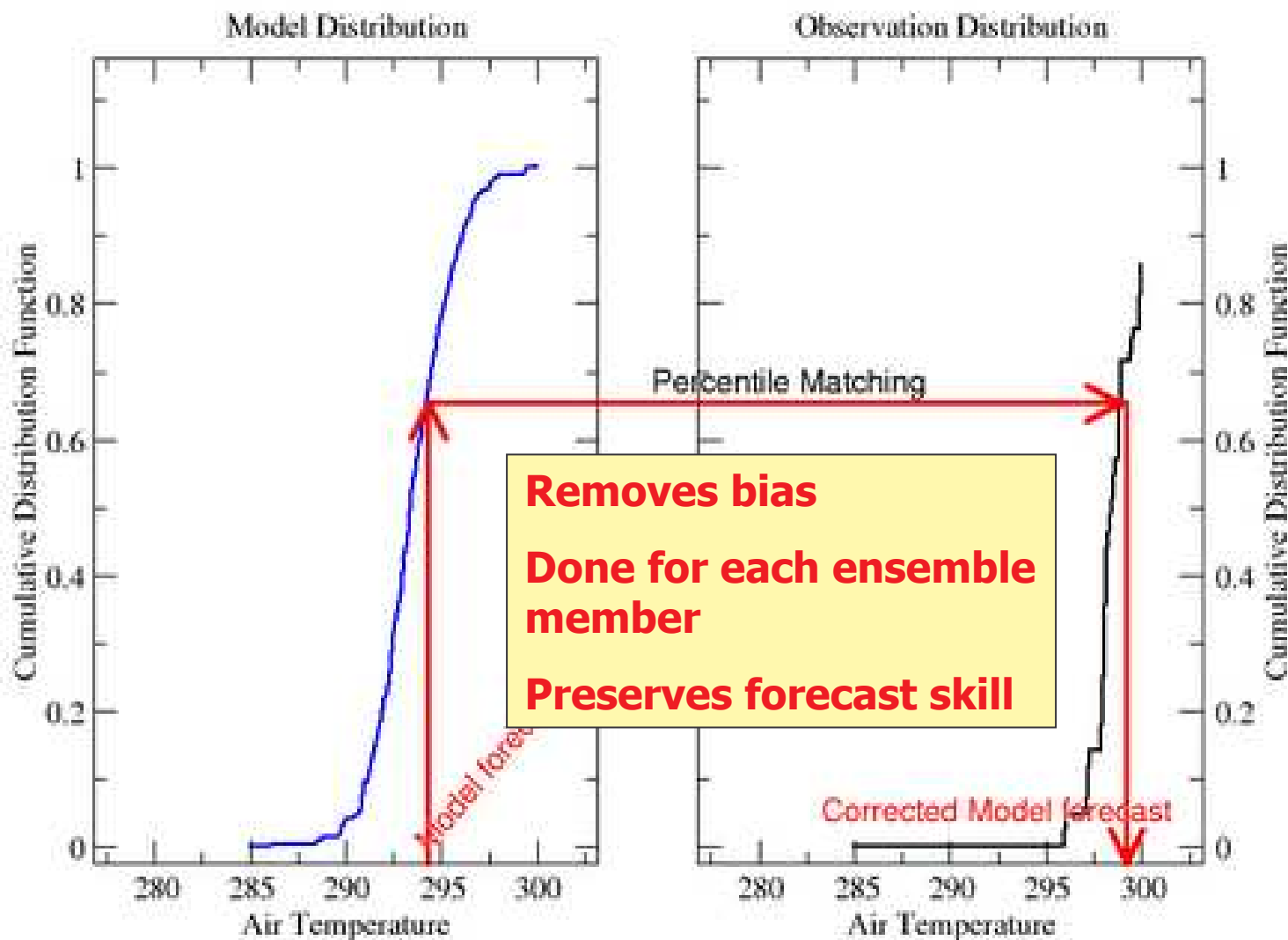


GCM Forcing Bias – Air Temp.

Monthly Mean Air Temperature Distribution

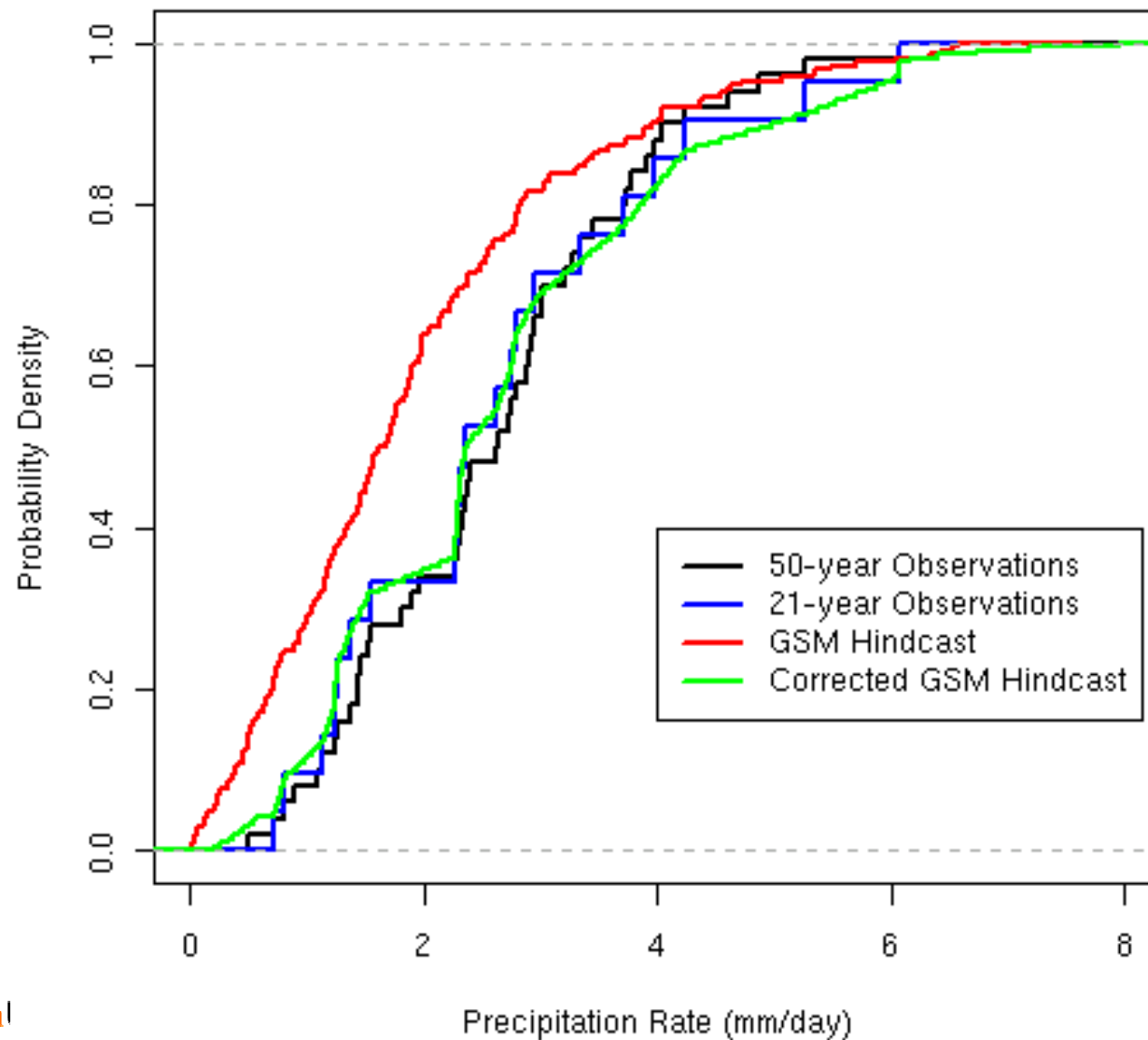


Bias Correction: Probability Mapping



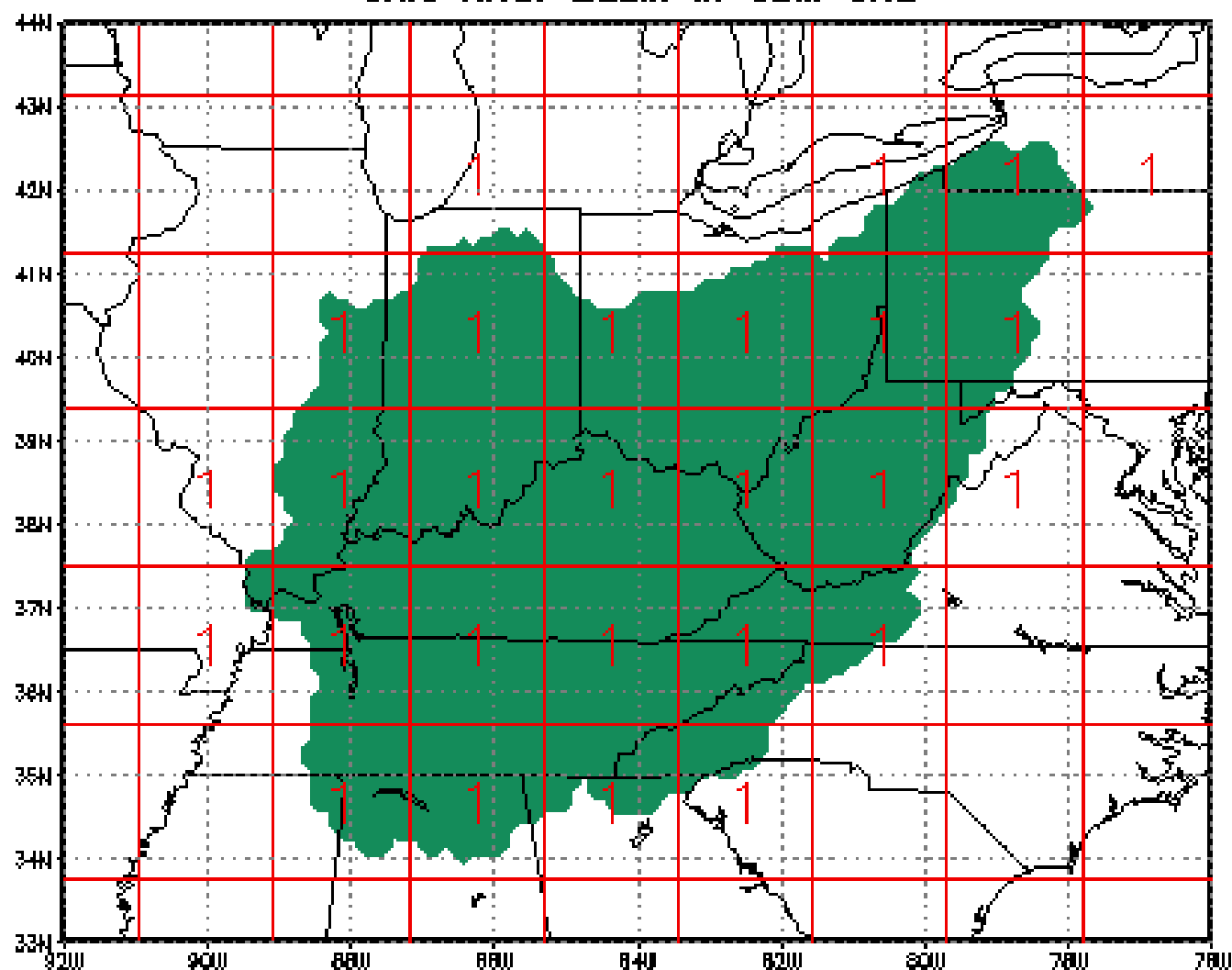
Corrected Forcing – Precipitation

Monthly Mean Precipitation Distribution and Bias Correction

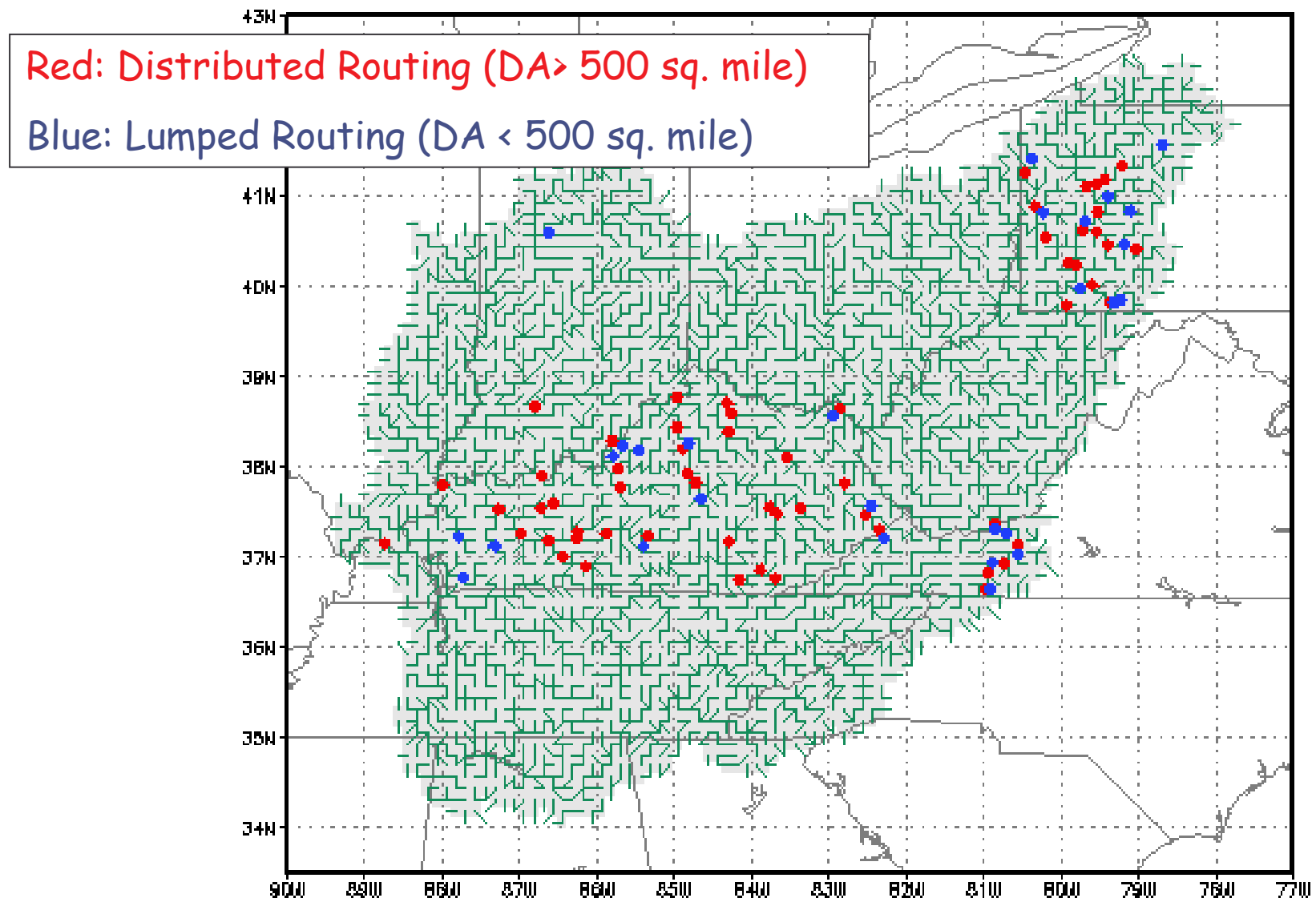


Downscaling

Ohio River Basin in GSM Grid



USGS Streamflow Stations over Ohio River Basin



Web Interface

VIC Seasonal Hydrology Forecast System: GSM - Streamflow Forecast - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://hydrology.princeton.edu/~luo/research/FORECAST/gsm.stream.php

SST Forecast

DEMETER Curriculum Vitae UW Hydrology Group Data Dissemination VIC Seasonal Hydrology Fo... Google Search: SST Forecast

Saturday, April 03, 2004

VIC Seasonal Hydrology Forecast System

Introduction **GSM** NSIPP ESP Documents Weekly Report

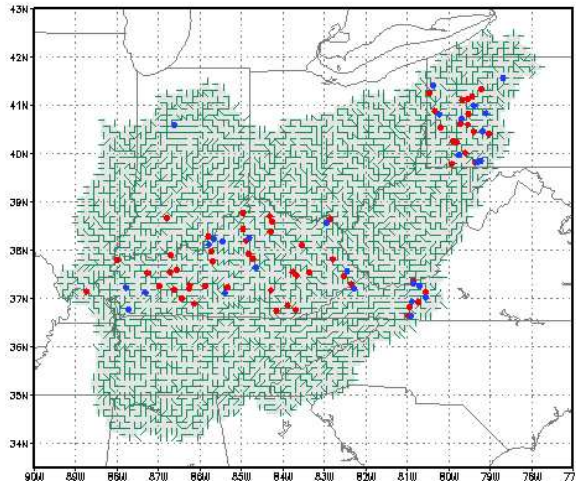
Overview
Bias Correction
Streamflow Forecast
Soil Moisture Forecast
Forecast Evaluation

Streamflow Forecast and Hindcast at selected USGS stations

Select from the drop menu or click on the USGS gages on the map to view the streamflow forecasts at the gage

GSM Forecast Set: 200402 Forecast Go

USGS Gage station: Lumped



Mon Nov 10 15:05:58 EST 2003

Comments

- **Updated** The routing network shown above (timestamp 2003-11-10) is the flow direction from Dag Lohmann. This flow direction is used in his NLDAS streamflow validation work. A comparison of this flow direction with EPA stream network can be found [here](#) (EPS file). There are a few problems with the plotting over the lake, but which are outside of the Ohio basin. updated on 2003-11-10.
- The drainage area displayed on the plot is provided by USGS. The actually drainage area used in the lumped routing model and distributed routing model can be found [here](#).
- The red dots are USGS gages with a drainage area larger than 500 sq. miles, and a distributed routing model is applied on these subbasins. The flow direction file provided by Dag Lohmann is used for this distributed routing model. The fraction file comes from UW which has 1 for most of the grids and only has values smaller than 1 on the Ohio basin boundaries. The blue dots are the USGS streamflow gages with a larger drainage area (>500 sq. miles), a simple lumped routing model is applied to these subbasins. The unit hydrograph has NOT been optimized at this time. But the results on monthly time scale are already quite good. There is still room to improve them by optimizing the UH function for each basin.

undated on 2003-11-20

Done

VIC Seasonal Rxvt xpdf: /tmp/Wi wind xpdf: /tmp/cha xpdf: /tmp/ban

52° 17:09

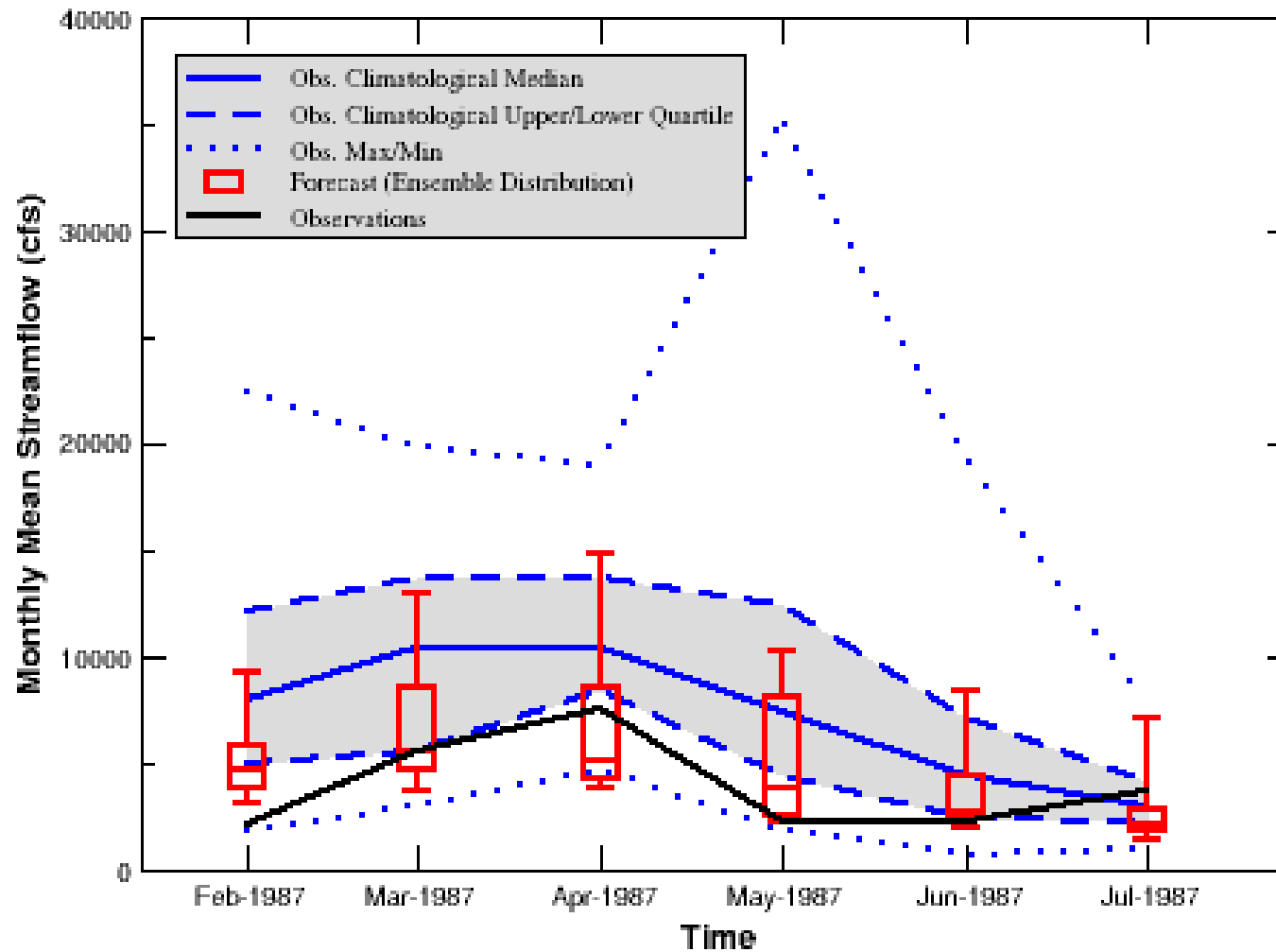


Prin

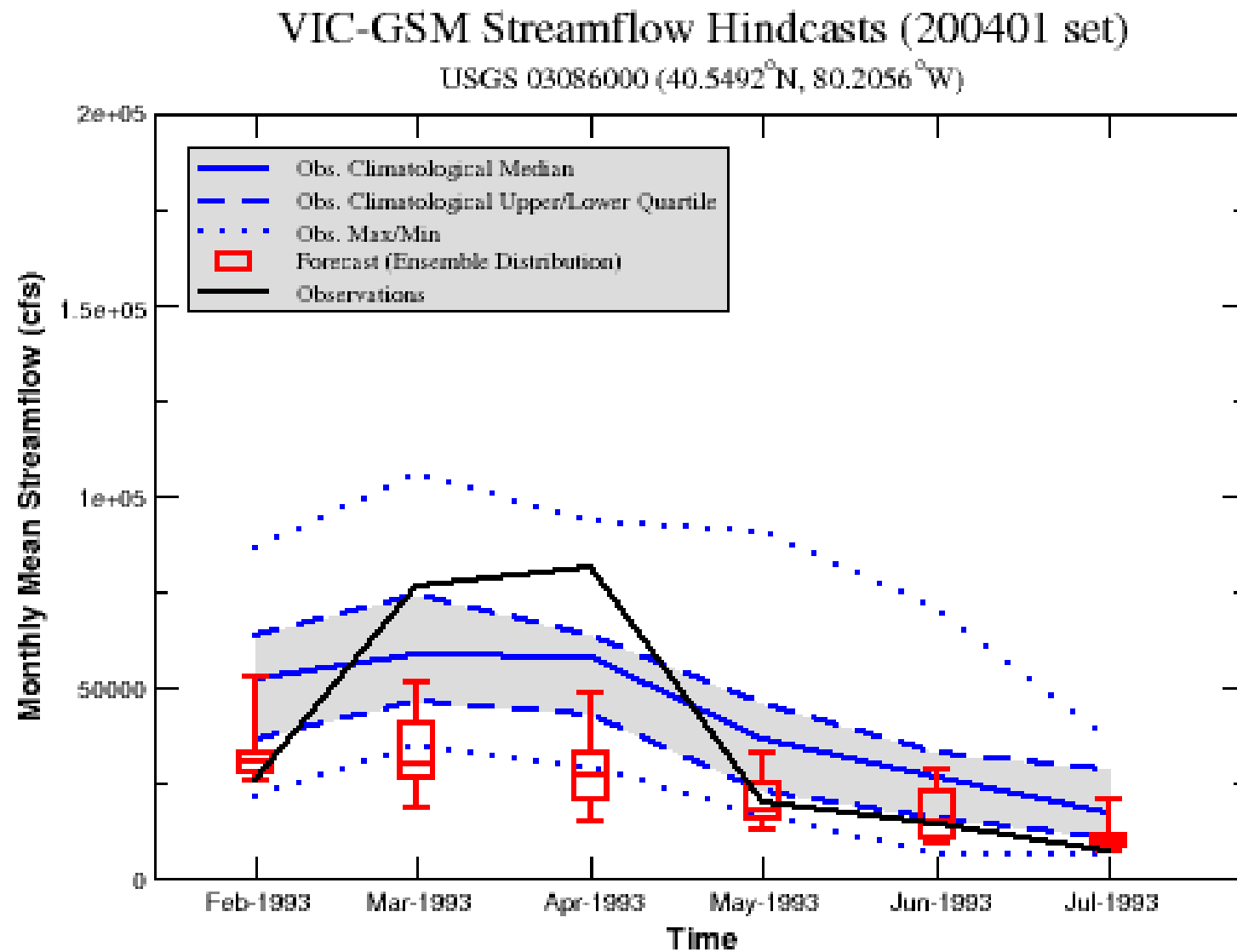
Hindcast Evaluation (Example 1)

VIC-GSM Streamflow Hindcasts (200401 set)

USGS 03373500 (38.6672°N, 86.7922°W)



Hindcast Evaluation (Example 2)



Problems with the Initial Implementation

The overall forecast skill in the Ohio is quite low.

- n Bias correction scheme performs well.
- n VIC and the routing model have errors, but they can be calibrated and are not a major error source.
- n The transfer of GCM monthly precipitation to 1/8 degree daily precipitation (spatial downscaling and weather generator) is one source of uncertainty and errors.
- n The major problem is lack of skill in the GCM seasonal forecasts.



Current Status of Our Forecast System

- n The initial system was up and running in an operational mode from late 2003 to August 2004 when a major disk failure took place.
- n The focus over the last few months, and at present, is developing a new approach to address the following problems:
 - n Lack of skill in atmospheric forcing
 - n Uncertainties in spatial downscaling and “weather” generator
 - n Producing redundant ensembles at multiple levels.
- n We are also working on improving the system code to make it more flexible for future integration with NLDAS and LIS.



Planned activities for 2005-2007

1. Expansion of the forecast area

2. Developing a multi-model seasonal forecast ensemble system, which could include observations (as a prior).

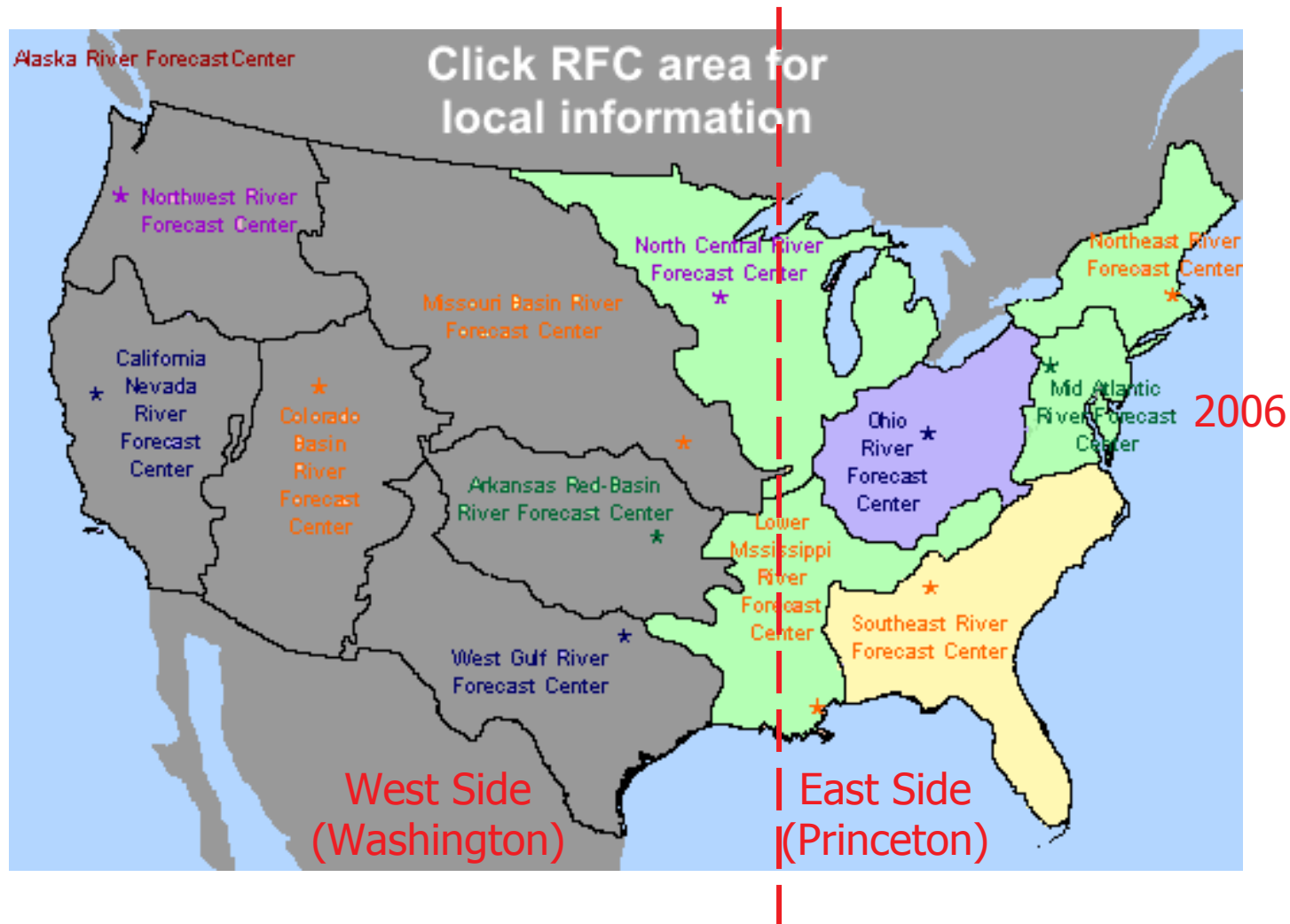
This can be extended to the hydrological streamflow forecasting, using multi-model (LSM) Bayesian merged ensembles and multi-model, ESP-based ensembles as a prior.

3. Structuring the ensemble system within NLDAS and VIC for the southeastern U.S., and carrying out forecast evaluation.

4. Understanding the potential for seasonal predictability and forecast usefulness for the southeastern U.S.



US East-side Hydrologic Forecast System



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New bias and downscaling approach

- n Merge information from multiple sources instead of relying solely on a climate model forecast
 - n Climatological distribution from in-situ observations
 - n Seasonal forecast from multiple climate models
 - n Climate indices (current and outlook)
- n Compute directly at the spatial scale that is suitable for the hydrologic application ($1/8^{\text{th}}$ deg or smaller), which avoids spatial downscaling.
- n The hydrological ensembles are generated from the merged GCM ensemble/s and in-situ information (posterior distribution) at the local spatial scale.



Bayesian Merging of Information

Bayes Theorem

$$p(\theta | y) = \frac{p(\theta, y)}{p(y)} = \frac{p(\theta) p(y | \theta)}{p(y)}$$

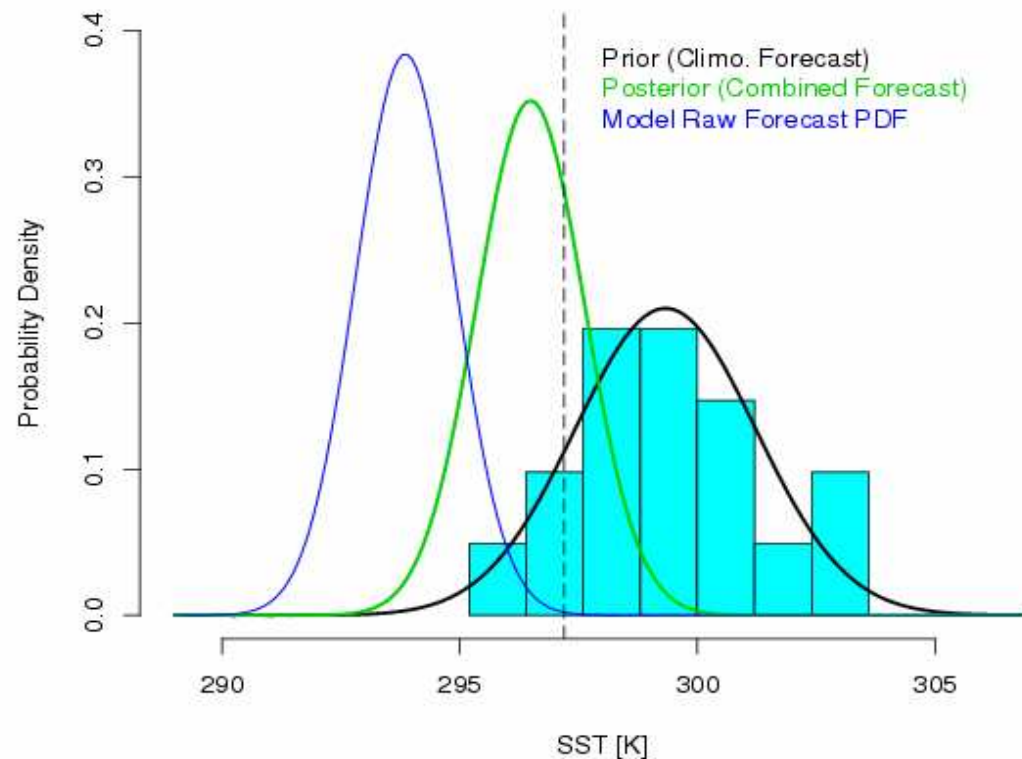
Posterior

1/8th degree
scale variable

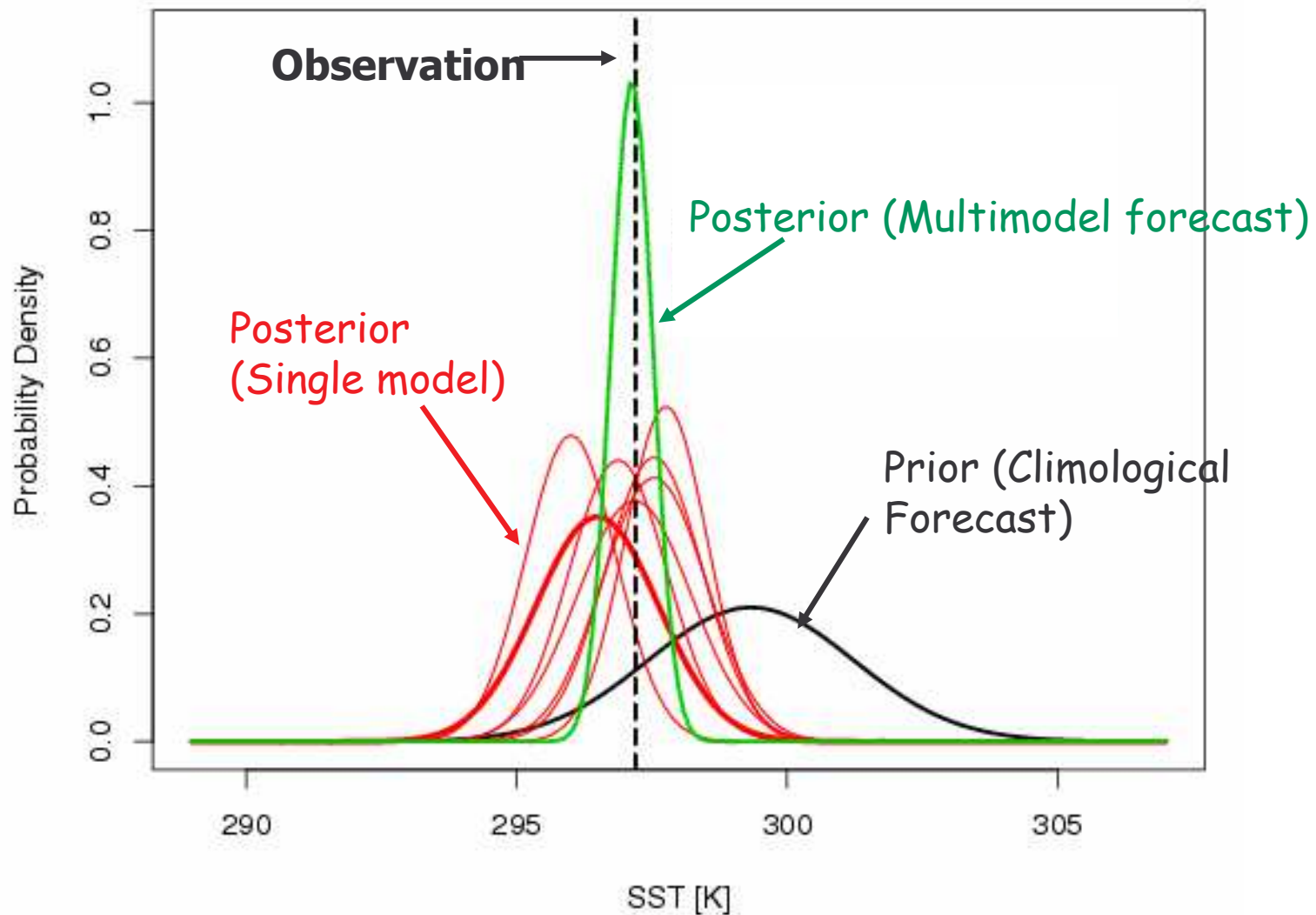
GCM-scale
variable

Prior
(local
climatology)

Likelihood function
(relates local scale
to GCM scale)



Merging Multiple Model Forecast with Climatology



Example: SST Forecast

n Seasonal SST forecast from ECMWF DEMETER project

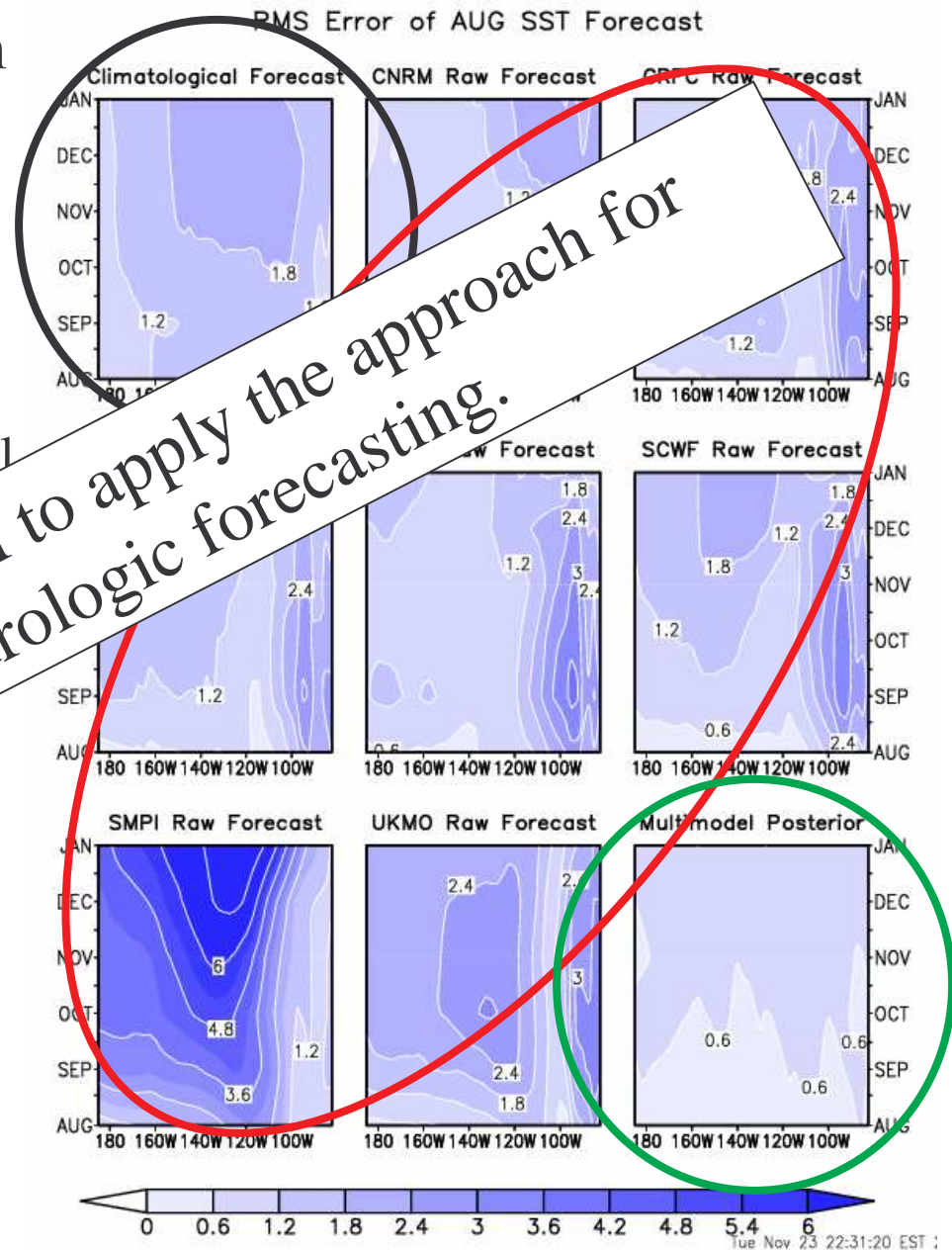
- n 7 climate models
- n 6 months forecast starting August
- n 9 ensembles from each model
- n 20 years (1980-1999)

n RMS error of all forecast initial

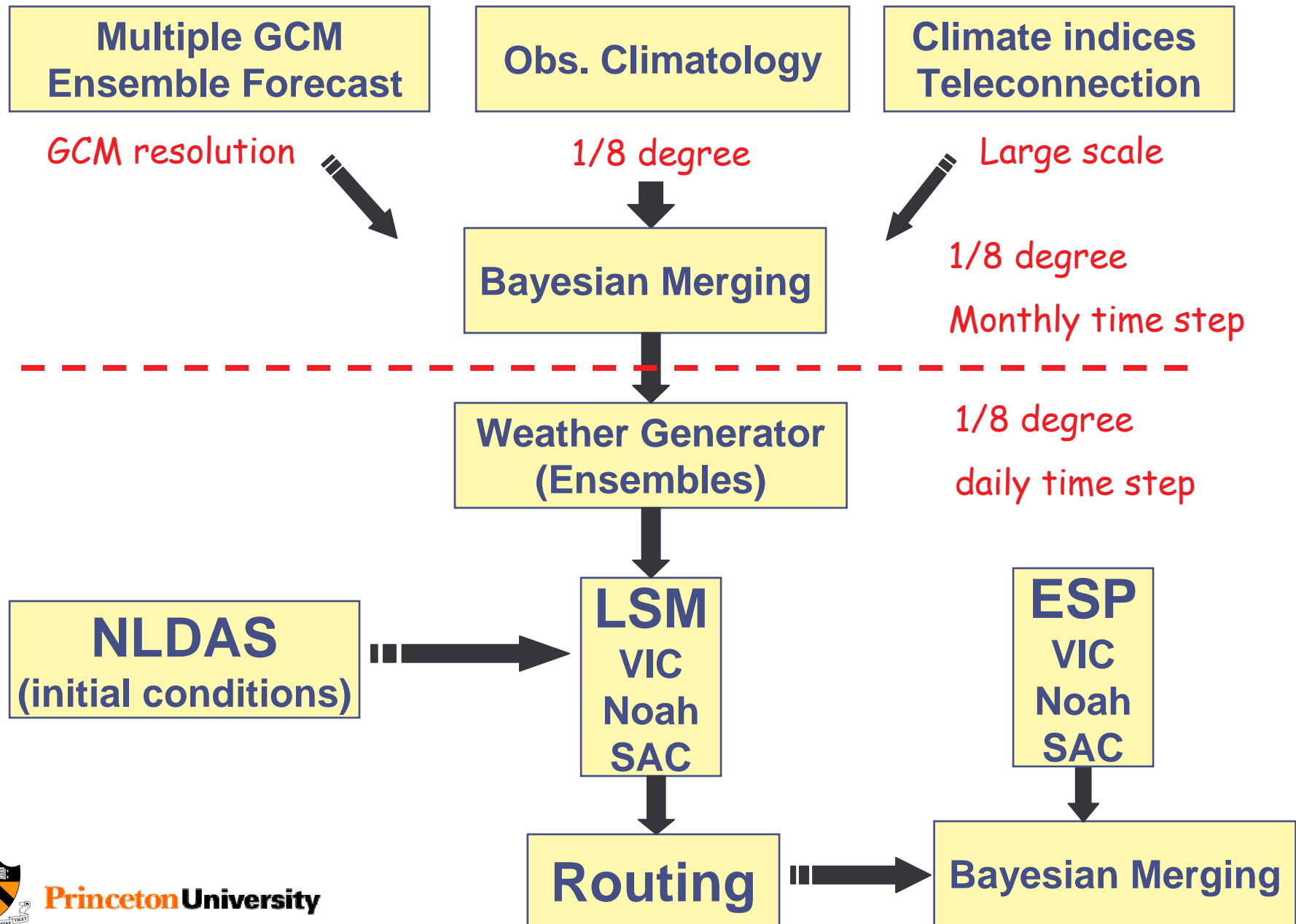
n Forecast skill

n The model posterior analysis has the smallest RMS error

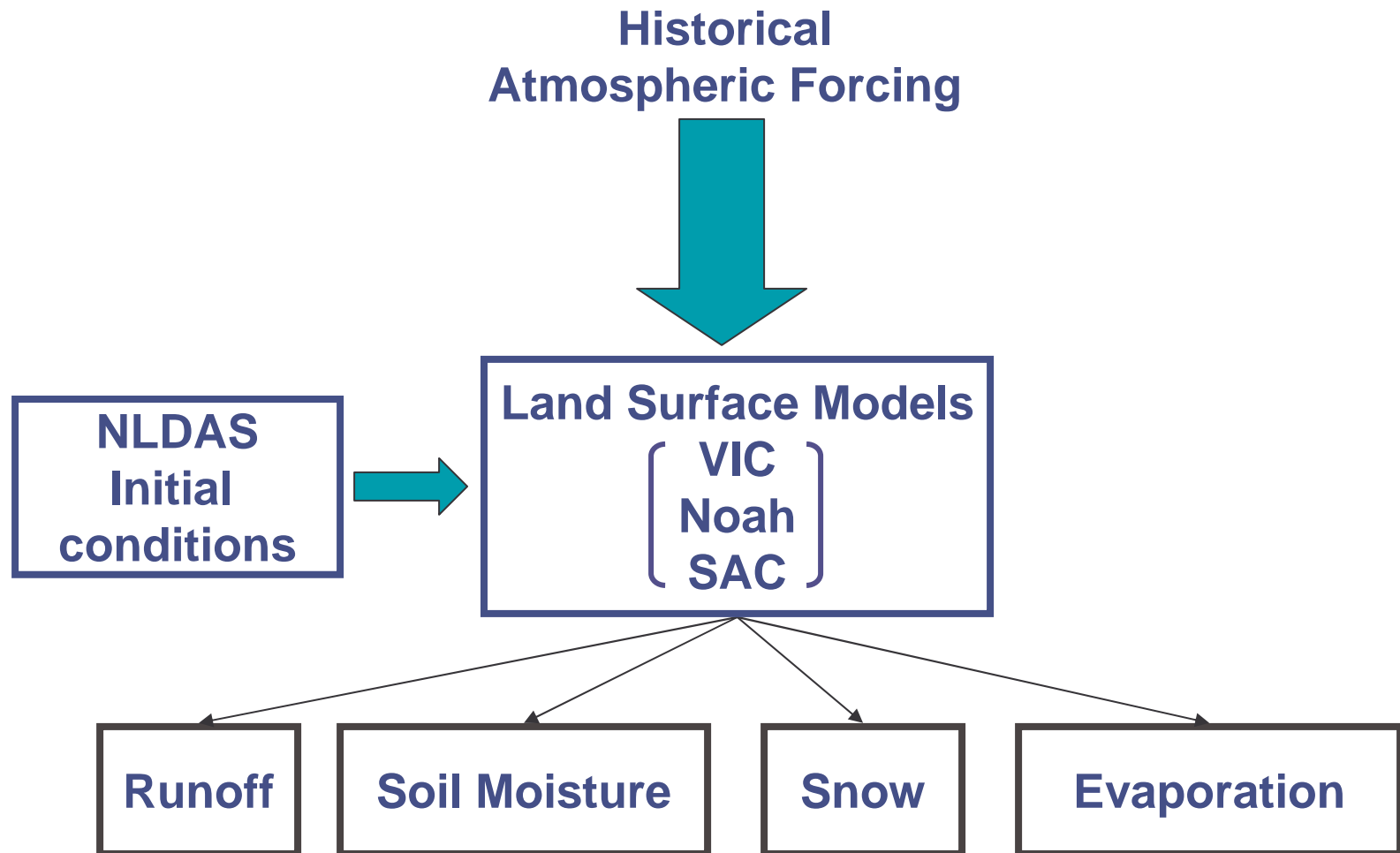
There is great potential to apply the approach for seasonal hydrologic forecasting.



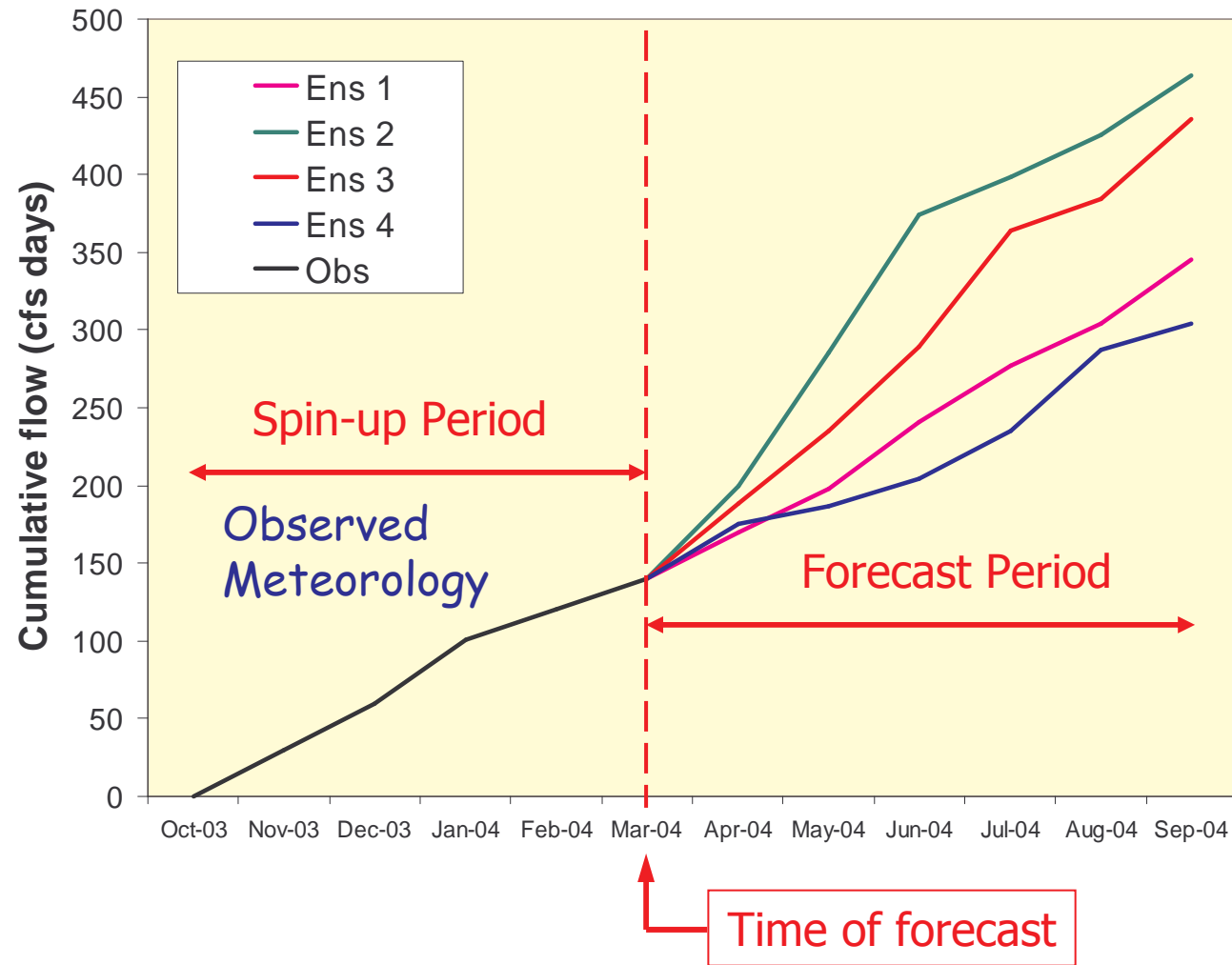
Bayesian system now under development



Hydrologic Model-based ESP



Hydrologic Model-based ESP



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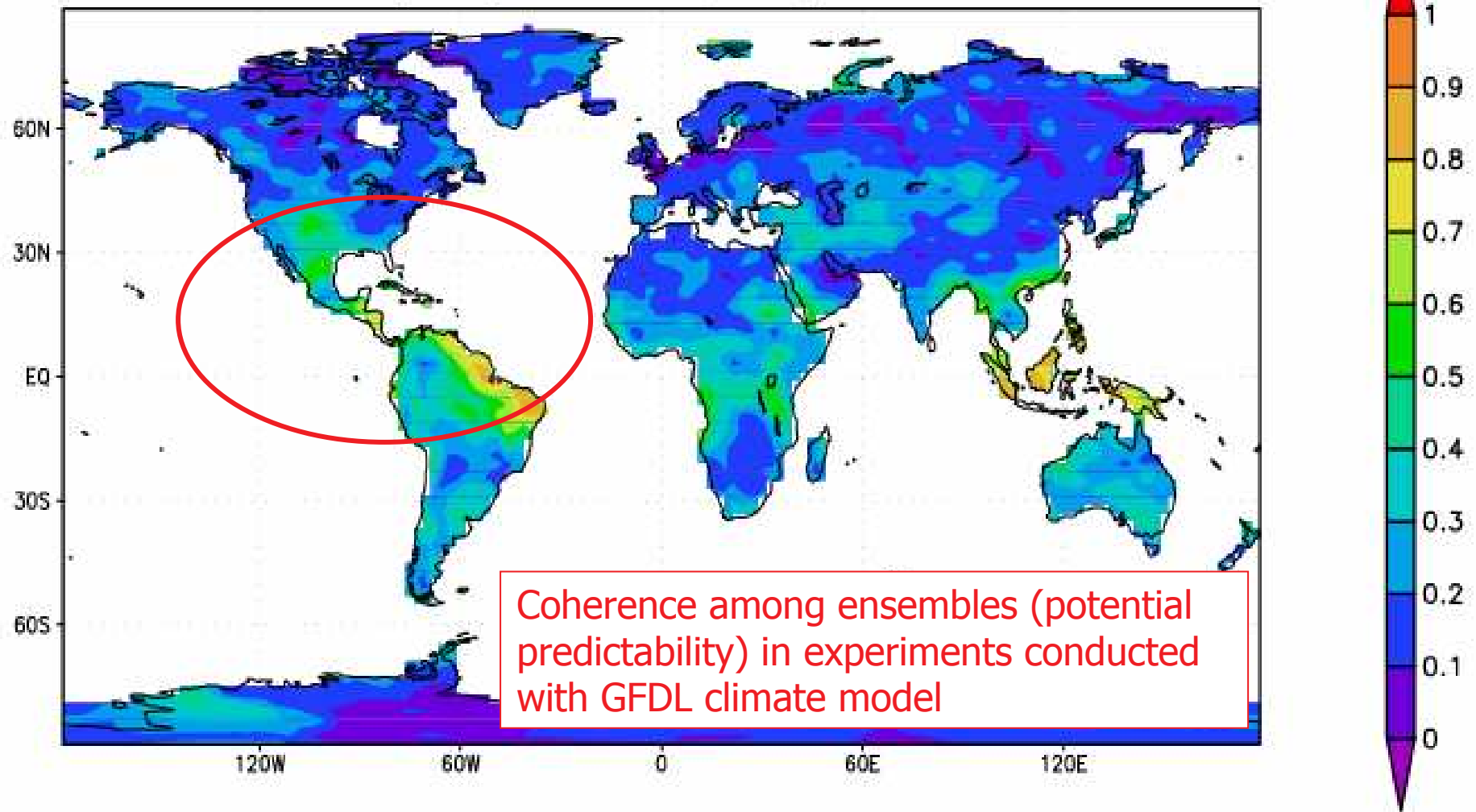
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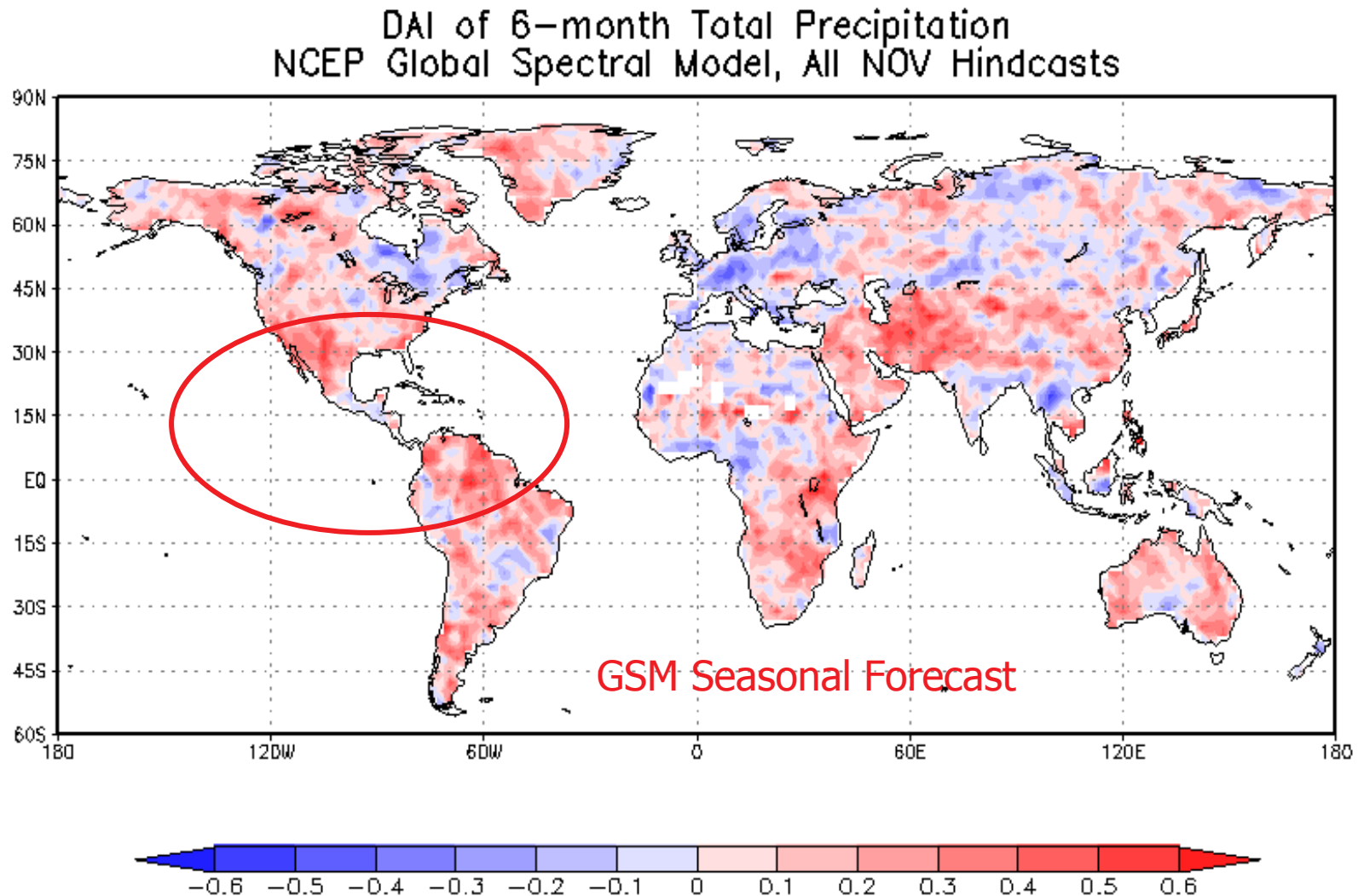


Potential Predictability of Precipitation

$\Omega(\text{AOL})$ ANN precipitation



GSM Forecast Skill

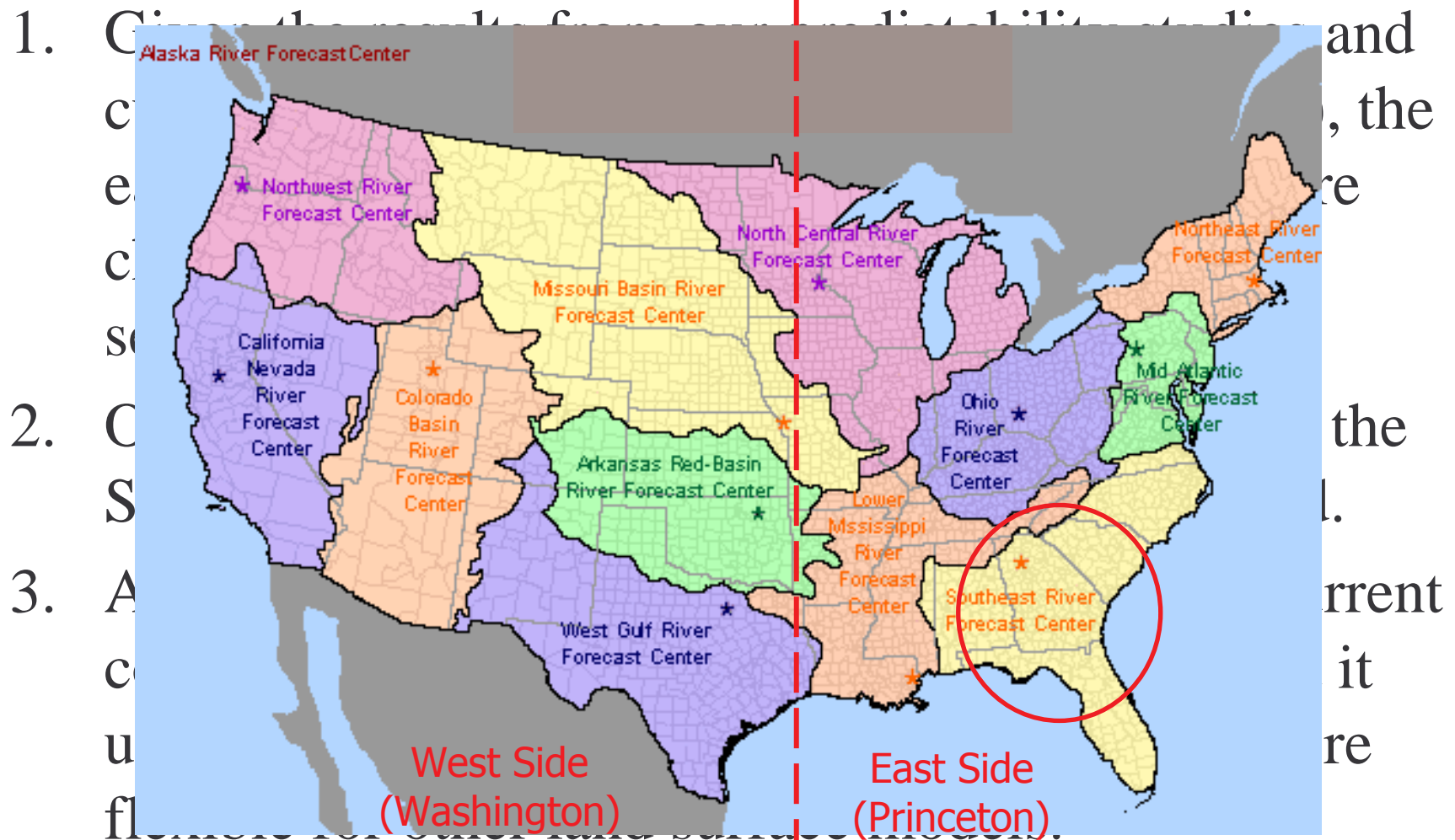


Tue Apr 6 16:24:33 EDT 2004



Princeton University

Summary and Future Directions



Proposed collaborations with NOAA

1. I see the seasonal hydrologic forecast system as part of the Test-bed facility (transition of research into operations).
2. Need to develop HDL/OH collaborations on evaluation of the forecasts and their useful for water management.
3. I would like to encourage the establishment of a Hydrologic Ensemble Forecasting System (HEFS) project utilizing a university-NOAA (NASA?) partnership as with NLDAS.



Thank you



Princeton University